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ZOOLOGICAL AND BIOLOGICAL METHODS OF RESEARCH.

BY HARRISON ALLEN, M.D.

The influence of methods of zoology upon biological science has, in some instances, led to confusion of terms. The great or primary principles of life are certainly of deeper significance than the limited and often arbitrary deductions of zoology would lead us to infer. An anatomical process as considered within the range of its own forms, and having no direct reference to the needs of the systematists, often ends without the intervention of any of the hypotheses of evolution; not that they fail to support such hypotheses, but that the anatomist finds the nomenclature adopted by the naturalist to be remote from his purpose.

We propose contrasting a few examples of zoological and biological methods as suggested chiefly by the study of deformations.

These may be freely epitomized as follows: I. The principles of reversion as contrasted with gemmation. II. The terms general and special. III. Teleology as contrasted with morphology. IV. Methods of growth as distinct from typical forms.

I. All monsters are now known to be the results of operation of law. Indeed, we have never advanced from the position taken by Montaigne that "from omniscience nothing but the good, the usual, and the regular proceeds; but we do not discern the disposition and relation."

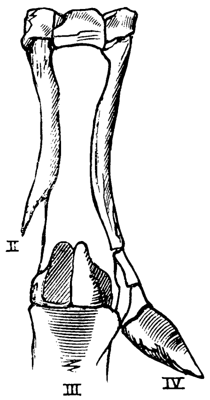
The variance from the type to which the monster belongs cannot for a moment be compared to the variation from the characters of a known specific or generic formula. Indeed, it is singularly rare to have any portion of a monstrosity recalling the normal relation of parts of any animal congeneric with it. If any one compares, for example, the head of a dolphin with its anterior nares in a position somewhat similar to that of the central cavity in the face of a Cyclops sheep, he will find that the rudimentary nasal bones and the exposed position of the vomer, as well as the extraordinary projection of the maxillary processes in the front of the central opening, all suggest that the Cyclops, so far as its osseous parts are concerned, is dolphin-like; it will be seen, nevertheless, that the validity of such a comparison is at once dissipated when the intermaxillæ of the dolphin are detected occupying their normal relation to the superior dental arch; while these bones have never descended from the vertex in the Cyclops.

In the same way, the mammal having cleft palate, in which the vomer is seen occupying a position on the plane of the roof of the mouth, is not to be placed in the same group with the Chelonian skull, in which the vomer normally exhibits an exposure in the hard palate, for the reason that this cleft palate is due in the mammal to some error of union between the fronto-nasal process and the related maxillary arches; this—the real cause of the deformation—is not in any way affected in the Chelonian.

It would appear that a lapsus in the course of the development of a highly specialized animal will cause the defect to be fixed at a point so low that no intelligent study can be made between it and the normal "relation and disposition" of parts in another animal equally if not more highly specialized than the one in which the deformation is seen. It is evident that no defect in a ruminant can be said to be a reversion to a cetacean—when the latter is the more specialized of the two animals.

In the same way, great care should be exercised in comparing mammals, exhibiting defects in the numbers of toes, with related zoological types. Starting with the tentative point that the most generalized form of the mammalian limb is a five-toed segmented axis, we have the type to which all other forms can be compared. This comparison is most successfully carried out in the carpus and tarsus. Confining our remarks to the posterior limb, we find the first, second, and third toes uniting through the intervention of the cuneiform bones with the scaphoid, while the fourth and fifth toes unite directly with the cuboid bone. Any descent from this number of five is seen to occur upon the sides, so that the first and fifth toes are lost before the second and fourth; and if the animal possesses but one functionally active toe, it is invariably the third. Reversion, by which any specialized form of foot shows a tendency to return to a more generalized expression, is thought to be exhibited in the horse. A horse having functionally active splint bones would thus suggest a

Fig. 1.



reversion to Hipparion. Mr. Wood-Mason (Proc. Asiatic Soc. Bengal, Jan. 1871, p. 18) has figured (Fig. 1) and described a horse's foot in which one of the splint bones was hoof-bearing.

While accepting the premises by which can be demonstrated the line of descent of the horse from Hipparion, we think that the proof of the argument rests not upon the number of digits, but upon their "disposition and relation." The tarsus is the key to all parts of the foot arranged distally to it. Observers have too often neglected the necessity of tracing supernumerary toes back to their corresponding tarsal elements, thus impairing the force of their conclusions, and confounding a zoological inference (*i. e.*, a reversion of a special to an embryonic form) with another larger principle (*i. e.*, gemmation).

In some of its expressions, at least, reversion and gemmation are terms of equal value; thus, if we look upon the limb as a bud, the toes partake of the same value as the main shaft of the limb, and may be called distal buds—diverging as rays from the tibia and fibula; the mere substitution of the term bud for toe is here of the first importance, for we can thereby account for any number of toes as well as any interference in the order of the bones of the normal foot. Whereas, if we use the term toe instead of bud, we are limited strictly to the foot as determined by its own tarsus, and anything in excess of that number is atypical, and has no zoological equivalent. It is evident that the mere duplication of a "toe" is no proof of its reversion to anything, whether it occur in the horse or in man. Let us suppose, for example, that a child is born with six toes, it does not follow that the sixth toe is an example of reversion, but is a mere expression of an excessive tendency to budding. In like manner, the so-called second hoof of the horse may have no connection with either the fourth or the second toes, but may be a mere bud or graft from the third. (Fig. 2.)

Prof. Leidy (Proc. Acad. of Nat. Science, 1871, 112) has called attention to the foot of a horse in which the splint bone, becoming functionally active, would appear to be an instance of reversion toward Hipparion. A careful examination of this specimen has convinced the writer that four toes are here present instead of three, and that the first and second are united in a common shaft, bearing a hoof, occupying a position of the functionally active

Fig. 2.

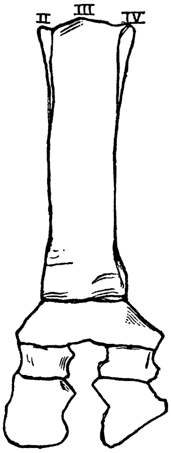
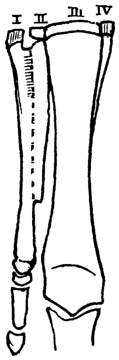


Fig. 3.



splint bone, as in the case recorded by Mason. This specimen cannot be considered, therefore, as a reversion to a three-toed, nor even to a congeneric four-toed ancestor, since the first toe is present. (Fig. 3.)

Fig. 4.

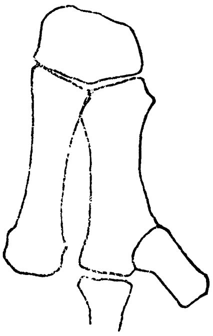
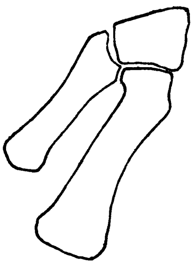


Fig. 5.



Otto (Monstr. Anat. Des.) has figured numbers of examples of six-toed and six-fingered monsters. In some of these the additional digit is a distinct bud from the shaft of a marginal metacarpal or metatarsal bone (Ibid., Tab. xxv., Fig. 9). (Fig. 4.) In others the new appendage extends upward to the tarsus (Ibid., Tab. xxv., Fig. 11). (Fig. 5.) We would place the first-mentioned of these in the group of rayed processes of Goodsir; and in the second group we would place those alone whose divergent rays enter directly into the construction of carpus and tarsus respectively. In this restricted sense, reversion is of subordinate value as compared to the principle of budding.

M. S. Arloing (Ann. des Sciences Naturelles, viii., 1867, 55, pl. II.) figures and describes the anterior extremity of a horse, in which the bovine-like hoof is dependent upon an atypical budding from the end of the third toe (see Fig. 2).

In like manner the union of parts usually distinct, as, for example, the produced digits of a hog—forming a solid terminal bone incased in a single hoof—should not even remotely suggest any variation in the type. Such unions are not known to yield corresponding change in the carpus. For figures, see Otto, loc. cit., and Struthers, Edin. Phil. Journal, N. S., 1863, 272.

II. Pursuant to the method as above suggested, the terms general and special, as applied to the limitation of types, can be made to assume a deeper significance. It is accepted that, in the mammalian limb of a five-toed form having the digits of about equal lengths, we have what is accepted to be a generalized "disposition" of parts; but, at the same time, the muscles in a series of limbs so characterized will have varying degrees of specialization. Thus the separation of the deep from the superficial flexor, in the hand of man, creates a high degree of specialization compared with the paw of the opossum, in which the division of the common flexor is barely manifested.

So with the inferior extremity of man we find all the essential elements of the osseous structure of a remarkably low degree of generalization, so far as the parts below the neck of the femur are concerned. But the bone at that point and the hip-bones present an extraordinary degree of special development. Here, then, is a limb found in a highly specialized zoological form, which is specialized only towards its proximal end.

In the arrangement of its muscles, particularly in the posterior femoral group, we get a marked degree of specialization. The muscles which in most animals belong to the extrinsic group, such as the *biceps flexor*, *semi-membranosus*, and *semi-tendinosus*, are removed entirely from the trunk, and pass between segments of the limb. This arrangement, joined to the excessive development of the *glutæus maximus*, enables man to assume the erect position. The consequences of this assumption are so varied and important as to give the clue to some of his best physical characteristics. It is thus seen that the arrangement of these muscles is of great value, although it need not be taken into consideration if we view the limb, as is commonly done, from the standpoint of the osseous parts only.

III. Now this posterior femoral group of muscles yields an upward prolongation of fascia, which is intimately identified with the *biceps flexor*. This prolongation extends as far as the sacrum, and has received the name of the great sacro-sciatic ligament. Very rarely the *biceps flexor* continues muscular along this tract, thus affording an illustration of reversion. But singularly enough, this reversion is not to the higher quadrumana, where the sacro-sciatic ligament is even less pronounced than in man. Probably we will find the type to which this upward prolongation of the biceps can be located somewhere in the link uniting the lemurs with the rodents. Teleology has been contemptuously regarded. Kitchen Parker has called it "a pretty gilded ball," that lies by the side of the path of severe study, and if it attract attention at all, does it at the expense of true progress. But it will not do to ignore teleology. Here is a group of highly specialized muscles based upon a trifling difference in the arrangement of muscular fibres, which is nevertheless indirectly the cause of retardation or deviation of parts in themselves of great morphic significance.

IV. The several types which have received the names vertebrata, articulata, mollusca, and radiata are no longer considered as expressions of distinct ideas, so much as different expressions of the same idea. The forces of nutrition in all the types are obedient to the same laws. It is evident that it is more interesting to study these laws than the resultant forms. There are no dissonant laws existing in the several types, but a few harmonious laws existing in all.

The law of bilaterality, for example, is seen in all the types. The law of the spiral, the law of gemmation, the laws of conjugation and fissuration are all actively expressed in the tissues.

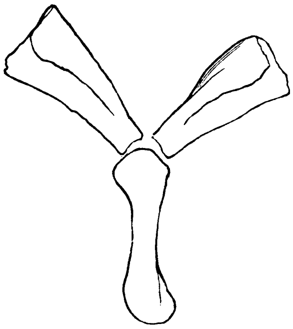
To these accepted data we may be allowed to add another, viz., the law of radiate nutrition. This is one of the most pronounced phases of growth force. Numerous examples of radiate skeletons are seen in the Protozoa, where nothing else in the way of formed tissue need be seen. It is, therefore, together with the force of the spiral, among the *first* expressions of growth force. It gives the entire group of the Radiata its most conspicuous superficial character. In the lower Annulosa it operates in more restricted fields, but often so powerfully as to be alone subordinate to the law of bilaterality. In the Mollusks it appears to occupy a position below both bilaterality and the force of the spiral, although in the compound Ascidians we see examples of it, as well as in the minute anatomy of the tests of many bivalves.

We called attention to the existence of a radiated type of nutrition in vertebrates in 1872 (Proc. Acad. Nat. Sci., 1872, 42), and particularly invited attention to the arrangement of the bones of the pelvic and shoulder girdles.

Prof. Theodore Gill[1] has also suggested the identification of homologous parts, from a central or determinate part outwards. Within certain limitations (viz., the acceptance of the limb as a peripheral quantity, potentialized from distal to proximal ends) this view is in harmony with our own.

The law of radiate nutrition which so powerfully impresses the tissues at both the shoulder and pelvis, maintains its authority in the event of deformation. Thus, in a double monster, the right scapula of one individual, the left scapula of the opposite individual (Fig. 6), and a humerus, bearing ulna, radius, and carpus, will be arranged as rays from a central point. It is evidently impossible to identify this humerus and its associated segments with either of the individuals.

Fig. 6.



In another example the parts of the limb were arranged bilaterally. One division represented the distal portion of the right limb of an individual, the other portion of its opposite—the limb gradually ending in the femur as a single structure. Tracing this single femur toward the trunk, we found, as in the preceding instance, it bore the relation of a ray to the ossicles representing the pelvic bones.

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[1] Smithsonian Miss. Coll., 247, p. xiv.

In addition to radiate nutrition, as shown in small and subordinated areas in an animal in which another type of nutrition is dominant, we may have, as in vertebrates, the principle of bilaterality announcing itself in small territories of tissue apparently uninfluenced by the larger expression of force operating in the same direction elsewhere. Indeed, we may say that bilaterality is not merely a principle of right and left adaptation; but may be found operating anywhere, and, perhaps, in more than one place at a time. Thus, the development of the sternum is independent of the development of the vertebral column. It arises between the ends of opposed costæ, and when this occurs in a single symmetrical individual, it would appear to be influenced by some deep-lying typal condition. But in double monsters the sterna, when present, do not belong to either individual, but arise between the right ribs of one individual and the left ribs of its opposite. Such a sternum thus takes its place on either side of the dual organism. It is very evident that these sterna cannot be identified with either individual, but are rods, symmetrically segmented, orignating *de novo* in an intra-costal space, and entirely irrespective of the bodies from which these costæ spring.